for multiple antennas systems in the publication by G.J. Foschini and M.J. Gans, "On Limits of Wireless Communications in a fading Environment when Using Multiple Antennas", *Wireless Personnal Communications* 6:311-335, 1998. However, it has been demonstrated (in the publication by P. Loubaton, M. Debbah and M. de Courville, "Spread OFDM Performance with MMSE Equalization", in *International Conference on Acoustics, Speech, and Signal Processing*, Salt Lake City, USA, May 2001) that V-BLAST algorithms are not suited for conventional SOFDM systems due to the averaging of the SNRs (signal/noise ratios) at the receiver across the carriers during the despreading step. Moreover, such approaches lead to a tremendous decoding complexity due to the computation of several pseudo inverse matrices.

A need therefore exists for an OFDM communication system and decoding algorithm for use therein wherein the abovementioned disadvantage(s) may be alleviated.

Statement of Invention

In accordance with a first aspect of the present invention there is provided a spread OFDM wireless communication system as claimed in claim 1.

In accordance with a second aspect of the present invention there is provided a spread OFDM wireless communication system as claimed in claim 10.

In accordance with a third aspect of the present invention there is provided a receiver, for use in a spread OFDM wireless communication system, as claimed in claim 11.

In accordance with a fourth aspect of the present invention there is provided a receiver, for use in a spread OFDM wireless communication system, as claimed in claim 18.

In accordance with a fifth aspect of the present invention there is provided a method, of operating a receiver in a spread OFDM wireless communication receiver, as claimed in claim 19.

In accordance with a sixth aspect of the present invention there is provided a method, for performing minimum mean square error equalization in a spread OFDM wireless communication system, as claimed in claim 27.

In one aspect, the present invention provides a new, efficient yet simple, low complexity decoding algorithm for an enhanced OFDM modulator.

Preferably the OFDM modulator is based on a Walsh-Hadamard transform, allowing exploitation of the mathematical properties of a Walsh-Hadamard precoder.

In one form, the new decoding algorithm consists in splitting a received block into two equal parts, one of the parts being decoded first and then subtracted from

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the received vector to suppress part of the interference and the other of the parts being decoded next. This iterative procedure can be further extended by successive block splitting and results in a multi-resolution decoding algorithm. An attractive property of this algorithm is that although it still relies on the computation of pseudo-inverses, the expressions of these pseudo-inverses are easy to derive and consist simply in the product of a diagonal matrix by a Walsh Hadamard transform. Thus, using Walsh Hadamard spreading sequences, the inherent complexity penalty of a V-BLAST decoding schemes is simply removed. This allows a significant gain in performance (e.g., around 3-4dB compared to MMSE SOFDM) with only a modest increase in complexity, which motivates:

i) the use of such new modulation schemes in practice and

ii) their proposal as a solution for future wireless LAN standards.

The following technical merits of the new multi-resolution decoding algorithm can be highlighted:

- Low arithmetical complexity compared to existing SIC BLAST techniques with same or better performance.
- Flexibility and scalability of the method (it is possible to adjust the number of iterations to be performed based on a performance/complexity tradeoff).
- Can be combined into all OFDM standards as a proprietary transmission mode (since it can be

Claims

1. A spread OFDM wireless communication system (100) comprising:
   at a transmitter (110-140)
      means for transmitting a spread OFDM signal;
   at a receiver (160-180)
      means for receiving the spread OFDM signal;
      means for equalizing the spread OFDM signal
      means for splitting the equalized spread OFDM signal into a first plurality of portions including a first portion and a second portion;
      means for making a decision on the second portion to produce a decided second portion;
      means for subtracting the decided second portion from the received spread OFDM signal to produce a first difference signal; and
      means for equalising and processing the first difference signal to recover the first portion of the received signal in which interference due to second portion interfering terms is substantially reduced.

2. The system of claim 1 further comprising:
   at the receiver (160-180)
      means for making a decision on the first portion to produce a decided first portion;
      means for subtracting the first portion from the equalised spread OFDM signal to produce a second difference signal; and

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means for equalising and processing the second difference signal to recover the second portion of the received signal in which interference due to first portion interfering terms is substantially reduced.

3. The system of claim 2 wherein the receiver (160-180) further comprises means for repeating processing a predetermined number of further times, with the recovered first and second portions in place of the decided first and second portions, to recover more reliable estimates for the first and second portions.

4. The system of claim 1, 2 or 3 further comprising:
at the receiver (160-180)
means for splitting the recovered received signal into a second plurality of portions greater in number than the first plurality of portions and including a first subsequent portion, a second subsequent portion, a third portion and a fourth portion;
means for subtracting the second subsequent portion, the third portion and the fourth portion from the received signal to produce a first subsequent difference signal; and
means for processing the first subsequent difference signal to recover the first subsequent portion of the recovered received signal in which interference due to second, third and fourth portion interfering terms is substantially reduced;

means for making a decision on the first subsequent portion to produce a decided first subsequent portion;

means for subtracting the first subsequent portion, the third portion and the fourth portion from the received signal to produce a second subsequent difference signal; and

means for processing the second subsequent difference signal to recover the second subsequent portion of the recovered received signal in which interference due to first, third and fourth portion interfering terms is substantially reduced;

means for making a decision on the second subsequent portion to produce a decided second subsequent portion;

means for subtracting the first subsequent portion, the second subsequent portion and the fourth portion from the received signal to produce a third difference signal;

means for processing the third difference signal to recover the third portion of the recovered received signal in which interference due to first, second and fourth portion interfering terms is substantially reduced;

means for making a decision on the third portion to produce a decided third portion;

means for subtracting the first subsequent portion, the second subsequent portion and the third portion from the received signal to produce a fourth difference signal;

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means for processing the fourth difference signal to recover the fourth portion of the recovered received signal in which interference due to first, second and third portion interfering terms is substantially reduced; and means for making a decision on the fourth portion to produce a decided fourth portion.

5. The system of claim 4 wherein the receiver (160-180) further comprises means for repeating processing a predetermined number of further times, with the decided first subsequent portion, the decided second subsequent portion, the decided third portion and the decided fourth portion in place of the recovered first subsequent portion, the recovered second subsequent portion, the recovered third portion and the recovered fourth portion respectively, to recover more reliable estimates for the first subsequent portion, the second subsequent portion, the third portion and the fourth portion.

6. The system of claim 4 wherein the second plurality of portions is an integer multiple of 2 that is greater than 2.

7. The system of any preceding claim wherein the means for equalising and processing comprises:

first matrix multiplication means for multiplying by a first diagonal matrix having elements dependent on channel coefficients; and

second matrix multiplication means for multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.

8. The system of any preceding claim wherein the means for equalising and processing comprises means for performing minimum mean square error equalization.

9. The system of any preceding claim wherein the means for transmitting a spread OFDM signal comprises means for spreading by performing a Walsh Hadamard transform.

10. A spread OFDM wireless communication system (100) comprising:

at a transmitter (110-140)

means for transmitting a spread OFDM signal;

at a receiver (160-180)

means for performing minimum mean square error equalization having:

first matrix multiplication means for multiplying by a first diagonal matrix having elements dependent on channel coefficients; and

second matrix multiplication means for multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.

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11. A receiver (160-180) for use in a spread OFDM wireless communication system (100), the receiver comprising:

means for receiving a wireless spread OFDM signal;

means for equalizing the spread OFDM signal

means for splitting the equalized spread OFDM signal into a first plurality of portions including a first portion and a second portion;

means for making a decision on the second portion to produce a decided second portion;

means for subtracting the decided second portion from the received spread OFDM signal to produce a first difference signal; and

means for equalising and processing the first difference signal to recover the first portion of the received signal in which of interference due to second portion interfering terms is substantially reduced.

12. The receiver of claim 11 further comprising:

means for making a decision on the first portion to produce a decided first portion;

means for subtracting the first portion from the equalised spread OFDM signal to produce a second difference signal; and

means for equalising and processing the second difference signal to recover the second portion of the received signal in which interference due to first portion interfering terms is substantiallyreduced.

13. The receiver of claim 12 wherein the receiver further comprises means for repeating processing a predetermined number of further times, with the recovered first and second portions in place of the decided first and second portions, to recover more reliable estimates for the first and second portions.

14. The receiver of claim 11, 12 or 13 further comprising:

means for splitting the recovered received signal into a second plurality of portions greater in number than the first plurality of portions and including a first subsequent portion and a second subsequent portion, a third portion and a fourth portion;

means for subtracting the second subsequent portion, the third portion and the fourth portion from the recovered received signal to produce a first subsequent difference signal; and

means for processing the first subsequent difference signal to recover the first subsequent portion of the recovered received signal in which interference due to second, third and fourth portion interfering terms is substantially reduced;

means for making a decision on the first subsequent portion to produce a decided first subsequent portion;

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means for subtracting the first subsequent portion, the third portion and the fourth portion from the received signal to produce a second subsequent difference signal;

means for processing the second subsequent difference signal to recover the second subsequent portion of the recovered received signal in which interference due to first, third and fourth portion interfering terms is substantially reduced;

means for making a decision on the second subsequent portion to produce a decided second subsequent portion;

means for subtracting the first subsequent portion, the second subsequent portion and the fourth portion from the received signal to produce a third difference signal;

means for processing the third difference signal to recover the third portion of the recovered received signal in which interference due to first, second and fourth portion interfering terms is substantially reduced;

means for making a decision on the third portion to produce a decided third portion;

means for subtracting the first subsequent portion, the second subsequent portion and the third portion from the received signal to produce a fourth difference signal;

means for processing the fourth difference signal to recover the fourth portion of the recovered received signal in which interference

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due to first, second and third portion interfering terms is substantially reduced; and means for making a decision on the fourth portion to produce a decided fourth portion.

15. The receiver of claim 14 further comprising means for repeating processing a predetermined number of further times, with the decided first subsequent portion, the decided second subsequent portion, the decided third portion and the decided fourth portion in place of the recovered first subsequent portion, the recovered second subsequent portion, the recovered third portion and the recovered fourth portion respectively, to recover more reliable estimates for the first subsequent portion, the second subsequent portion, the third portion and the fourth portion.

16. The receiver of any one of claims 11-15 wherein the means for equalising and processing comprises:

first matrix multiplication means for multiplying by a first diagonal matrix having elements dependent on channel coefficients; and

second matrix multiplication means for multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.

17. The receiver of any one of claims 11-16 wherein the means for equalising and processing comprises means for performing minimum mean square error equalization.

18. A receiver (160-180) for use in a spread OFDM wireless communication system, the receiver comprising:

means for performing minimum mean square error equalization having:

first matrix multiplication means for multiplying by a first diagonal matrix having elements dependent on channel coefficients; and

second matrix multiplication means for multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.

19. A method of operating a receiver (160-180) in a spread OFDM wireless communication system (100), the method comprising:

receiving a wireless spread OFDM signal;
equalizing the spread OFDM signal
splitting the equalized spread OFDM signal into a first plurality of portions including a first portion and a second portion;
making a decision on the second portion to produce a decided second portion;
subtracting the decided second portion from the received spread OFDM signal to produce a first difference signal; and
equalising and processing the first difference signal to recover the first portion of the received signal in which of interference due to second portion interfering terms is substantiallyreduced.

20. The method of claim 19 further comprising:

making a decision on the first portion to produce a decided first portion;
subtracting the first portion from the equalised spread OFDM signal to produce a second difference signal; and
equalising and processing the second difference signal to recover the second portion of the received signal in which interference due to first portion interfering terms is substantiallyreduced.

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21. The method of claim 20 further comprising repeating processing a predetermined number of further times, with the recovered first and second portions in place of the decided first and second portions, to recover more reliable estimates for the first and second portions.

22. The method of claim 19, 20 or 21 further comprising:

splitting the recovered received signal into a second plurality of portions greater in number than the first plurality of portions and including a first subsequent portion and a second subsequent portion, a third portion and a fourth portion;

subtracting the second subsequent portion, the third portion and the fourth portion from the recovered received signal to produce a first subsequent difference signal; and

processing the first subsequent difference signal to recover the first subsequent portion of the recovered received signal in which interference due to second, third and fourth portion interfering terms is substantiallyreduced;

making a decision on the first subsequent portion to produce a decided first subsequent portion;

subtracting the first subsequent portion, the third portion and the fourth portion from the received signal to produce a second subsequent difference signal;

processing the second subsequent difference signal to recover the second subsequent portion of the recovered received signal in which interference due to first, third and fourth portion interfering terms is substantially reduced;

making a decision on the second subsequent portion to produce a decided second subsequent portion;

subtracting the first subsequent portion, the second subsequent portion and the fourth portion from the received signal to produce a third difference signal;

processing the third difference signal to recover the third portion of the recovered received signal in which interference due to first, second and fourth portion interfering terms is substantially reduced;

means for making a decision on the third portion to produce a decided third portion;

means for subtracting the first subsequent portion, the second subsequent portion and the third portion from the received signal to produce a fourth difference signal;

processing the fourth difference signal to recover the fourth portion of the recovered received signal in which interference due to first, second and third portion interfering terms is substantially reduced; and

making a decision on the fourth portion to produce a decided fourth portion.

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23. The method of claim 22 further comprising repeating processing a predetermined number of further times, with the decided first subsequent portion, the decided second subsequent portion, the decided third portion and the decided fourth portion in place of the recovered first subsequent portion, the recovered second subsequent portion, the recovered third portion and the recovered fourth portion respectively, to recover more reliable estimates for the first subsequent portion, the second subsequent portion, the third portion and the fourth portion.

24. The method of claim 22 wherein the second plurality of portions is an integer multiple of 2 that is greater than 2.

25. The method of any one of claims 19-24 comprising:
multiplying by a first diagonal matrix having elements dependent on channel coefficients; and
multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.

26. The method of any one of claims 19-25 comprising performing minimum mean square error equalization.

27. A method for performing minimum mean square error equalization in a spread OFDM wireless communication system (100), the method comprising:

multiplying by a first diagonal matrix having elements dependent on channel coefficients; and

multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.